Potential cost-effectiveness of a maternal Group B streptococcal vaccine in The Gambia

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Highlights

- First cost-effectiveness analysis of a potential hexavalent GBS vaccine in a low-resource setting
- A hexavalent GBS vaccine could avert 55% of Gambian cases and 768 disability adjusted life years per year

- Maximum cost-effective price per dose would be 12 US$ (2016 US$)
- GBS incidence was the most influential parameter on the cost effectiveness ratio.

ABSTRACT

Objective: To estimate neonatal health benefits and healthcare provider costs of a theoretical Group B streptococcal (GBS) hexavalent maternal vaccination programme in The Gambia, a low-income setting in West Africa.

Methods: A static decision analytic cost-effectiveness model was developed from the healthcare provider perspective. Demographic data and acute care costs were available from studies in the Gambia undertaken in 2012-2015. Further model parameters were taken from United Nations and World Health Organisation sources, supplemented by data from a global systematic review of GBS and literature searches. As vaccine efficacy is not known, we simulated vaccine efficacy estimates of 50-90%. Costs are reported un US dollars. Cost-effectiveness thresholds of one (US$473, very cost effective) and three (US$1420, cost effective) times Gambian GDP were used.

Results: Vaccination with a hexavalent vaccine would avert 24 GBS disease cases (55%) and 768 disability adjusted life years compared to current standard of care (no interventions to prevent GBS disease). At vaccine efficacy of 70%, the programme is cost-effective at a maximum vaccine price per dose of 12 US$ (2016 US$), and very cost-effective at a maximum of $3/dose. The total costs of vaccination at $12 is $1,056,962 for one annual cohort of Gambian pregnant women. One-way sensitivity analysis showed that GBS incidence was the most influential parameter on the cost effectiveness ratio.

Conclusion: The introduction of a hexavalent vaccine would considerably reduce the current burden of GBS disease in The Gambia but to be cost-effective, the vaccine price per dose would need to be $12/dose or less.

INTRODUCTION

Group B streptococcus (GBS) is a leading cause of neonatal sepsis and meningitis worldwide and can lead to disabling long-term sequelae in up to 50% of meningitis survivors (1). A key focus for the 2030 sustainable development goals (SDGs) is to reduce the neonatal mortality rate (NMR) to 12/1000 livebirths in every country globally (2). The NMR in The Gambia, a low-income West-African country, has remained static over the past 10 years at 28/1000 livebirths. (3) Since 44% of under-five deaths occur during the neonatal period (first 28 days of life), and infection causes 51.8% of under-five mortality worldwide, tackling neonatal GBS infection could significantly reduce neonatal mortality (4,5).

Maternal vaccination against GBS is a global priority identified by the World Health Organisation (WHO) (6). Several maternal multivalent GBS capsular polysaccharide (CPS) protein-conjugate vaccines are currently undergoing Phase I/II randomised control trials (RCTs) in Europe, the USA and South Africa (7). A multivalent protein-based vaccine is also undergoing phase I/II trials in Europe. (8) Vaccines specifically for low- and middle-income countries (LMIC) are being developed using tetanus toxoid (TT) conjugates which could potentially replace one of the tetanus doses given in pregnancy in LMICs (7). Nevertheless, there is little information for healthcare providers about the vaccine's potential cost-effectiveness in low-income countries. An important criteria for a licensed GBS vaccine's adoption into Gavi, the Vaccine Alliance's portfolio, would be to demonstrate cost-effectiveness in low-income countries (9).

Previous cost-effectiveness studies of GBS vaccines (10) in low-income African countries such as Ghana exist but these models exclude countries such as the Gambia, which have far lower Gross Domestic Product (GDP), health spending and access to care than Ghana (which achieved middle income status in 2012) (11). The Gambia has relatively good health and cost information that allows the potential impact of a GBS vaccine to be evaluated (12,13). This study aims to more accurately

inform policymakers on the potential economic impacts and neonatal health benefits of a maternal multivalent GBS vaccination programme in the Gambia, an example of a low-income West-African country.

METHODS

Target population, subgroups, setting

Demographic data from a previously conducted prospective study of 750 mother-infant pairs from two government health centres in urban Western Gambia in 2014 (12,500 livebirths annually) identified risk factors for GBS colonisation, transmission to neonates and GBS disease. New-borns were followed until 90-days of age for disease, mortality and disability outcomes. There was one case of culture-positive GBS disease, giving an incidence of 1.3/1000 livebirths (12). This data represents a sample of convenience and the government hospitals selected represent the standard of care available to Gambian women and is thus representative of neonatal care in the Gambia (13,14).

Where GBS data from this cohort was unavailable, the following hierarchy of data were selected: local data from a neonatal infection study (13) and a cost analysis of pneumococcal disease treatment (15), country-specific data from the Institute for Health Metrics Evaluation (IHME), UN International Children's Emergency Fund (UNICEF) and WHO global health observatory (GHO) (3,5,14) (Table 1). For the remaining parameters, a literature review on PubMed was conducted (15–19). **[Appendix 1 and 2]**

Disability adjusted life year (DALY) measures

DALYs associated with each disease sequalae were calculated using disability weights from The Global Burden of disease (GBD) study 2016 (20). GBS-specific weights are unavailable so non-specific proxies

were used for each disease presentation. (20,21) **[Table 1]**. Life expectancy for those with disability was assumed to be 30 years based on neighbouring Senegal (22). The rates of GBS sequelae including from meningitis were sourced from other studies as long-term sequelae were unavailable in the Gambia (17,19,23).

Costs of disease treatment

Costs of treating neonatal patients were taken from a cohort study of neonatal sepsis at the Edward Frances Small Teaching Hospital from 2014 (13). As no separate costs for the treatment of pneumonia or meningitis or costs of sequelae of meningitis were available from this study, costs were taken from cost-effectiveness analysis of treating young infant and paediatric patients aged 4-24 months with pneumococcal disease in the Gambia, as the costs of treating GBS disease in neonates and young infants was deemed to be similar, based on similar length of treatment and cost of sequelae other than death (15). Family out-of-pocket costs for the care of GBS survivors were also sourced from this study. All prices were inflated to 2016 US$ using standard annual inflation rates (24). The length of stay was adjusted for neonates using local data on neonatal stay for non-specific meningitis, pneumonia and sepsis (13). **[Appendix 3]**

Intervention - Vaccine uptake was assumed to be 84.3%, the same as that for the tetanus toxoid (TT) vaccine in the Gambian study (12), assuming single dose late-third-trimester vaccination to replace one tetanus toxoid dose as per WHO recommendations (25). Vaccine wastage rate is assumed to be 10% (26). The vaccine efficacy is currently unknown, so the model was run at efficacies of 50%, 70% and 90% (10). Multiplying the estimated 97% serotype coverage of a multivalent vaccine by these efficacy rates provided a range of vaccine coverage from 48.5% - 87.3% for term infants. Vaccine

efficacy for pre-terms was calculated to be 83.1% of the efficacy for term babies. **[Appendix 4]** The maximum cost-effective price per dose includes the cold storage for a new vaccine.

Study perspective – The study is written from the perspective of the healthcare provider with additional out-of-pocket costs for families caring for affected neonates, explored in further analysis.

The model

A decision-analytic model was developed in *R* (fig. 1) from an existing UK model of GBS vaccination introduction (27). The model estimates a maximum vaccine price per dose threshold whereby a hexavalent CPS-TT third trimester GBS vaccination programme would be deemed cost-effective in the Gambia using GDP per capita calculations. The programme is deemed *cost-effective,* at a cost/DALY averted of less than 1420 US$, three times the Gambian Gross Domestic Product per capita (GDPpc) and *very cost-effective* if the cost/DALY averted is less than 473 US$, one times GDPpc (28,29).

The model assesses infant health outcomes from birth to 90 days of age of no intervention compared to the proposed strategy of vaccination. Beyond one year after birth, an annual discount rate of 3% (26) was applied to infant life years lost and healthcare costs for GBS disease survivors (27). Key model inputs for the base-case population are in **Table 1.**

A decision tree, created on *LucidChart*, illustrates the individual state-transition model with either strategy via embedded Markov nodes. The expectant mother can either be vaccinated or not. Each livebirth may be preterm or term infants who are GBS disease-free or GBS disease sufferers, defined as pneumonia, meningitis or sepsis (30). The infant is assumed to suffer from sepsis, meningitis or pneumonia independently and may recover without sequelae, disabling sequelae or death. Both

early (EOD) and late-onset disease (LOD) are generalised as GBS disease, as Gambian data was unavailable. We were unable to undertake situational analysis of stillbirths in the Gambia because this association was not investigated during any of the cohort studies. **[Fig. 1.]** The results are reported using the CHEERS checklist (31)

Sensitivity analysis

A one-way sensitivity analysis was carried out to show the uncertainty associated with each key parameter and its impact on the cost-effectiveness of the programme. One parameter at a time was varied to the maximum and minimum values of its range **[table 1]** whilst all other parameters were held to their base-case values. Probabilistic sensitivity analysis was used to determine the level of uncertainty associated with the calculated cost-effectiveness threshold by varying parameters simultaneously whilst keeping vaccine price per dose fixed. Cost-effectiveness acceptability curves were generated from 5000 simulated outcomes for prices $3 and $12.

Ethics Approval

This study was approved by the joint MRC Gambian Government research ethics committee, L2018.61, SCC 1350v4.

RESULTS

No intervention

With no intervention, at a GBS disease incidence in the Gambia of 1.3/1000 livebirths (12), an annual cohort of 89,000 livebirths (32) would face 116 cases: 25 babies would suffer from meningitis; 50 babies from sepsis; and 41 from pneumonia. 14 babies would have sequelae (meningitis=5, sepsis=9). There would be 44 GBS deaths (meningitis=5, pneumonia=14, sepsis=25) and 1384 DALYs. The total costs of no intervention for the healthcare provider are $15,373, which comprises hospital admission, hospital length of stay of 6, 10 and 11 days for babies with sepsis, pneumonia and meningitis respectively and the costs of antibiotics and fluid support. **[Appendix 4]** Family out-of-pocket costs would be $5,270; $376 per family caring for a child with GBS sequalae **[Table 2].**

Vaccination outcomes

At a calculated base-case vaccine efficacy for term infants of 70% and when serotype coverage is 97%, GBS vaccination could avert 55% of all outcomes, i.e. 768 DALYs, 64 GBS disease cases, seven GBS sequelae and 24 neonatal/young infant deaths. The provider treatment costs averted with vaccination are $6937, $9738 and $12,704 at vaccine efficacies 50%, 70% and 90% respectively. The family out-of-pocket cost savings range between $2084, $2926 and $3817 for vaccine efficacies 50%, 70% and 90% respectively. This represents twice to four times the annual minimal wage in the Gambia of $1610 (33). The total programme costs for 89,000 pregnancies in one year would be $1,056,962 per year. There are very modest GBS disease treatment cost savings for the healthcare provider of $9738 per year. Total family out of pocket costs per year (outside of the cost-effectiveness calculation) are reduced by $2926 per year.

Cost-effectiveness

187 Assuming 70% vaccine efficacy, the maximum cost-effective price per dose is $12 per dose.
188 The cost/DALY averted would be $1355, below the benchmark of three times the Gambian GDP per
189 capita ($1420). [Table 3] This maximum cost-effective price per dose would range from $8 to $16 at
190 vaccine efficacies of 50% and 90% respectively.
191 At $3/dose, the vaccination programme is very cost-effective at $365/DALY averted assuming
192 70% vaccine efficacy which is below the benchmark cost of $474 (GDPpc in the Gambia). **[Fig. 2]** The
193 incremental cost of the programme is $264,658. The treatment cost savings ($8534) are independent
194 of vaccine price per dose. The total programme costs are $295,404.
195
196 **Sensitivity analysis**
197 The tornado diagram [**Fig. 3.]** shows that the most influential parameter is the vaccine price per dose.
198 At $2 per dose, the cost effectiveness ratio (CER) is $253/DALY averted and at $20 per dose, the CER
199 is $2233/DALY averted. GBS incidence is the second most influential parameter. At a low GBS
200 incidence (0.73/1000 livebirths), the CER is more than double at $2419/DALY averted. The least
201 influential parameters are GBS disease treatment costs. For example, treating pneumonia at $88.8-
202 $159 leads to a CER ranging from $1354-1352.
203 For the base case scenario, probabilistic sensitivity analysis was carried out at vaccine prices of $3
204 and $12 per dose. According to uncertainty guidelines, at least 90% of iterations need to be under
205 the CER of $1419.6 (34). At $3/dose, 99.92% of iterations are below this threshold, while at a vaccine
206 price per dose of $12, 18.12% of iterations fall under the CER. These outcomes demonstrate the
207 influence of vaccine price on the GBS vaccine cost-effectiveness**. [Fig. 4.]**
208 Comparing the impact of disease incidence and vaccine efficacy on the results of the
209 probabilistic sensitivity analysis, **Fig. 5.** shows that vaccine efficacy is the most influential of the two.
210 Table 1 displays parameter values tested.

The cost-effectiveness acceptability curve in **Fig. 6.** shows how likely vaccination is to be cost-effective over doing nothing as willingness and ability to pay increases from 0 to $6000/DALY. While over 80% of iterations are cost-effective for willingness to pay of at least $1000/DALY when vaccine price is at $3/dose, a vaccine price of $12/dose means that similar cost-effectiveness levels are achieved at a willingness to pay of at least $3000/DALY.

DISCUSSION

Over a one-year period, an affordable, effective maternal GBS vaccine could prevent 768 DALYs, 64 cases, 24 neonatal and infant deaths and seven severely disabled survivors (55% of disease-burden) at a base-case vaccine efficacy of 70% in the Gambia. For higher vaccine efficacy of 90%, up to 72% of the disease burden could be prevented. However, we found that the costs of the standard of care for GBS were very modest, which reflects the limited facility to treat affected babies beyond antibiotic administration.

In order to be cost-effective, our model suggests that such a vaccine would have to be provided at a low cost of approximately $12 per dose at 70% efficacy ($8 and $16 for 50% and 90% efficacy respectively) and $3 assuming a threshold of the Gambian GDP per capita. The net annual cost of a GBS vaccination programme at $12 per dose would be $1,056,962. A three times GDP per capita threshold allows comparison of our study with others but this threshold may be an unrealistic option for The Gambia where budgets are especially constrained and resources may be allocated to other sectors (17,35). It is clear from this and other GBS cost-effectiveness studies in LMICs, that only modest vaccine prices could be supported, and affordability should be an important criterium for vaccine development. Our cost-effective price of $12 per dose and highly cost-effective price of $3 per dose is in line with other vaccinations provided to GAVI-eligible countries. For example, the pneumococcal conjugate vaccine (PCV 13) provided by Pfizer, also

235 recommended by the WHO for pregnant women is priced at $2.90 per dose to the 73 GAVI eligible
236 countries (36) and the pentavalent vaccine (tetanus, haemophilus influenzae type B, diptheria,
237 pertussis and hepatitis B is available to GAVI-eligible countries at $3/dose (37)
238
239 Published studies have estimated a higher threshold price for a GBS vaccine. In South Africa
240 at a vaccine price per dose of $20, the cost-effectiveness ratio at 70% vaccine efficacy is $1533 per
241 DALY averted (10). In the Gambia, if the same vaccine price was used the CER would be $2231 per
242 DALY averted. As there is a higher base-case-value of neonatal GBS disease incidence in South Africa
243 (a middle-income country), the ability of the vaccine to prevent disease appears greater. This,
244 combined with their higher treatment costs, leads to greater cost savings after introducing the
245 vaccine in South Africa than in the Gambia (10).
246 There are several differences between our CEA and other models. Firstly, our study used the
247 data from a neonatal and infant cohort to provide information on GBS disease. We included an
248 estimate of GBS attributable pneumonia (10,17,38), which was not included in other cost-
249 effectiveness analyses of GBS vaccines. As most infants with pneumonia will die without prompt
250 recognition and treatment, the addition of pneumonia is important in reducing the burden of death
251 in the neonatal and early infant period (39). The most influential factor in our sensitivity analysis was
252 disease incidence, indicating that investments in surveillance are most likely to reduce uncertainty
253 on cost-effectiveness.
254 The sub-Saharan Africa (SSA) study clustered countries with similar socio-economic
255 backgrounds together making generalised assumptions about healthcare settings. (17) Using Ghana
256 as an example of a low income country, the maximum cost-effective vaccine price per dose is $7 at
257 $350/DALY averted at a vaccine efficacy of 70%. (17) When our study is adjusted to these
258 assumptions, however, the CER is $544/DALY which is higher than this estimate likely due to our

lower disease incidence. Both previous studies assumed effectiveness from a trivalent vaccine, yet without serotype V, which is included in our study, such a vaccine would be less cost-effective in the Gambia. Differences in income and treatment costs in both the South Africa and the SSA study make comparisons between these studies and ours difficult. For example, in South Africa, the average length of hospital stay for neonatal meningitis was 17 days whilst in both the SSA and our study the median length of stay was 11 days. (15,40).

In comparison to other vaccines in the infant extended programme on immunisation in the Gambia, a GBS vaccine could be more cost-effective than the 13-valent pneumococcal conjugate vaccine (PCV). The PCV cost-effectiveness study measured the same disease presentations as our study, but only 65% of DALYs were averted compared to 72% for the GBS vaccine at 90% vaccine efficacy using similarly conservative estimates, making an effective case for the introduction of this hexavalent vaccine to prevent all forms of GBS disease in the Gambia. (26)

There are limitations to this study. This analysis is based on a single study of 750 women delivering in costal Gambia and, although this is the largest study of GBS disease in a low income setting, may not be representative of GBS incidence in the whole of the Gambia or other low income countries. Nonetheless the incidence used in our model is consistent with estimates of disease burden for Western Africa (41) We included only adult pregnant women and as 8.8% of pregnancies in the Gambia occur in women aged between 15-19 years our study may have underestimated vaccine impact in this vulnerable group as low maternal age is a risk factor for neonatal GBS disease (42,43). The static model used, which has been used for other cost effectiveness studies of GBS vaccine, does not enable us to assess potential changes in the incidence of GBS over time, or any indirect vaccine effects. Several other factors will affect the model and our results may therefore underestimate the cost-saving of a GBS vaccine. Firstly, the surveillance occurred over one year, and subsequent years may have revealed an increased disease

283 incidence which would increase the cost-effectiveness of our model. We were unable to include
284 indirect costs as these are not currently defined for maternal vaccination. Finally, although we
285 added family out of pocket costs to our model, we were unable to include all societal costs. For
286 parameters such as neurodevelopmental impairment, country-specific data was not available, thus
287 our estimates are derived from global estimates that may not represent The Gambia (19). However,
288 the degree of disability due to GBS meningitis is similar to that of other bacterial meningitis in
289 similar settings and this data was available from the Gambia.(15,23) Additionally, only GBS
290 moderate-severe sequelae were included because data on mild sequelae rates are less reliable,
291 especially in the Gambia. (19). Consequently, the model may underestimate some cases with
292 sequelae and their associated DALYs. While treatment costs in our model were modest, we
293 acknowledge that the length of hospital stay may vary for different causative pathogens. Only non-
294 pathogen specific costs were available since in most cases, blood cultures would not be taken
295 because of constrained resources and the reliance on families to pay for these tests. We did not
296 evaluate other options for GBS prevention and control as these were not available during the
297 cohort study. There is limited data on the implementation of IAP in labour in the Gambia. The
298 PregnAnZI trial (44) randomised 830 pregnant women in labour to have either a placebo or single-
299 dose oral azithromycin in Western Gambia and found that GBS colonisation was almost eliminated
300 in mothers after azithromycin treatment. Azithromycin is more feasible than intravenous RFB-IA
301 intravenous as it can be effective as late as two hours before delivery. Although this strategy has
302 the potential to address EOD, more information is needed regarding its impact on antimicrobial
303 resistance, the infant microbiome and other health outcomes before such a strategy can be widely
304 recommended (44). The strategy would not reduce the burden of late onset disease, which most
305 commonly presents as meningitis, so this burden would remain. Should this IAP strategy come into
306 practice in the Gambia, its cost effectiveness should be compared to vaccination.

Conclusion

A vaccine that is modestly priced is likely to be a cost-effective intervention in reducing GBS disease in the Gambia. Uncertainty regarding cost-effectiveness can be reduced by improving estimates on the burden of GBS disease, particularly disease incidence.

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Author contributions

KLD and CT conceived the original idea and commented on the manuscript. NA undertook the model design, analysis and manuscript drafting, KG had expert input into the model and commented on the manuscript, EC, BK, UE and UO had expert input into the manuscript. All authors approved the final manuscript draft.

Conflict of interests

NA, KG, KLD, EU, UO, EC, and CT declare no conflict of interests. BK is an advisor for Pfizer regarding GBS vaccines.

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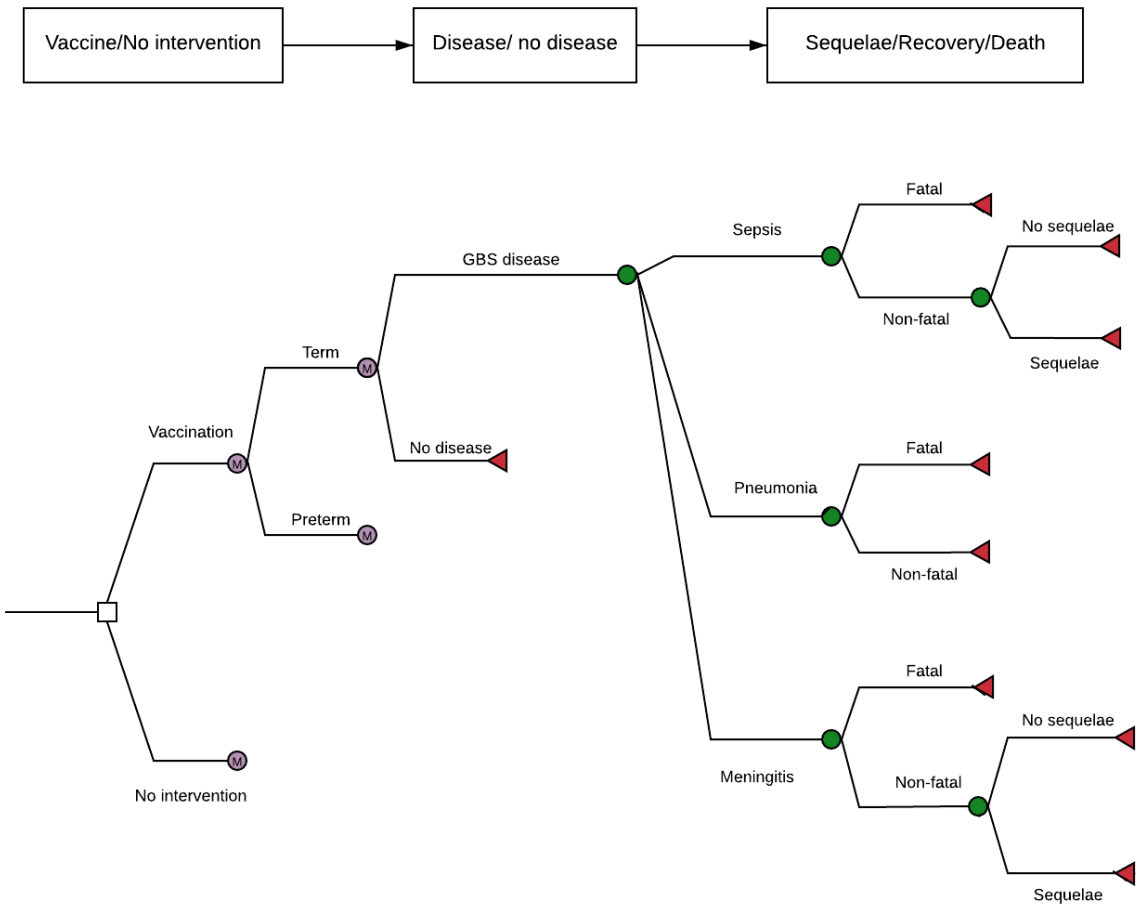


Figure 1: Decision tree for cost effectiveness analysis.

This diagram illustrates the two strategies in our model: the proposed Group B streptococcus (GBS) vaccination programme versus the current strategy of no intervention (no vaccination). Markov nodes denoted as M represent a continuation of the tree parallel to that of the other branch. For example, for both vaccination and no intervention, each livebirth can lead to GBS disease or no disease. GBS disease can present as sepsis, pneumonia or meningitis which can subsequently lead to death, disability or recovery.

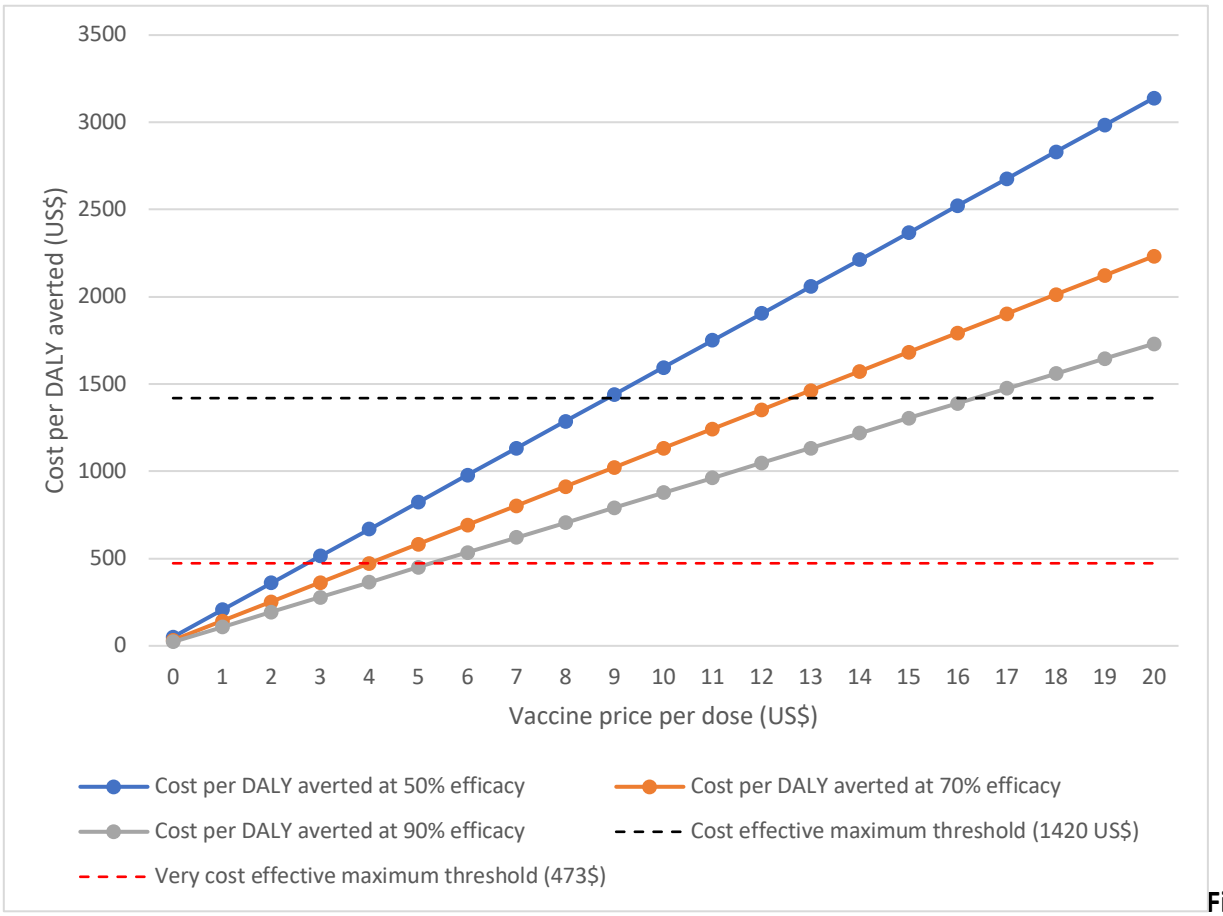
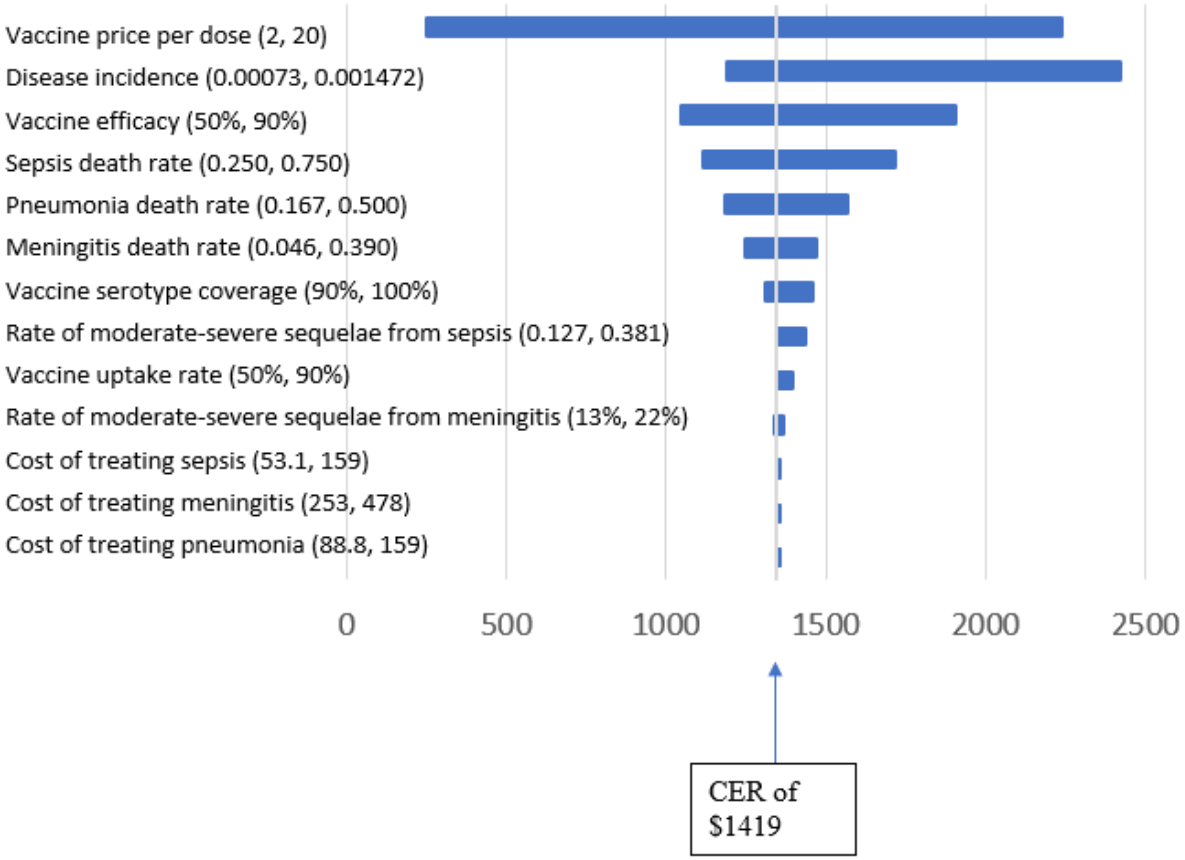


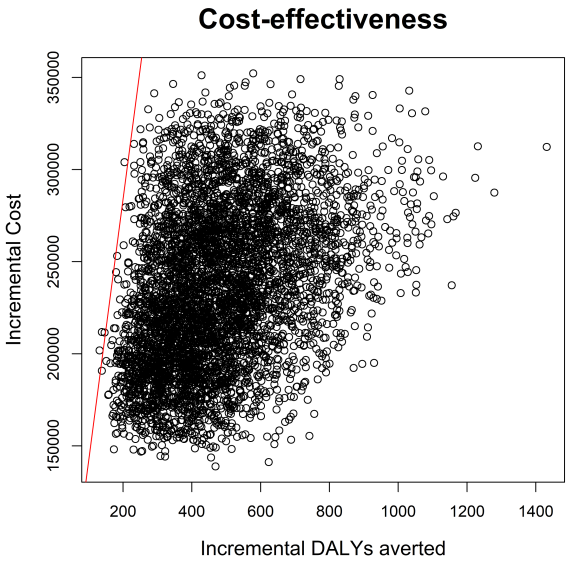
Figure 2: Incremental cost-effectiveness ratio of running models at vaccine efficacies 50%, 70% and 90%. *The maximum price per dose where the programme can be deemed cost effective (below the black hashed line) is $8, $12 and $16 at vaccine efficacies 50%, 70% and 90% respectively. The programme is deemed very cost-effective (below the red hashed line) at a maximum vaccine price per dose of $2, $4 and $5 at vaccine efficacies of 50, 70 and 90% respectively. DALY – disability adjusted life year; US$ - American dollars.*

Figure 3: A tornado diagram illustrating the uncertainty associated with key parameters in the model.

Vaccine price per dose has the largest effect on the cost-effectiveness of the vaccination programme whereas out-of-pocket costs have the least effect. CER – cost-effectiveness ratio.


Vaccine price per dose (2, 20)
Disease incidence (0.00073, 0.001472)
Vaccine efficacy (50%, 90%)
Sepsis death rate (0.250, 0.750)
Pneumonia death rate (0.167, 0.500)
Meningitis death rate (0.046, 0.390)
Vaccine serotype coverage (90%, 100%)
Rate of moderate-severe sequelae from sepsis (0.127, 0.381)
Vaccine uptake rate (50%, 90%)
Rate of moderate-severe sequelae from meningitis (13%, 22%)
Cost of treating sepsis (53.1, 159)
Cost of treating meningitis (253, 478)
Cost of treating pneumonia (88.8, 159)
0
500
1000
1500
2000
2500
CER of $1419

533



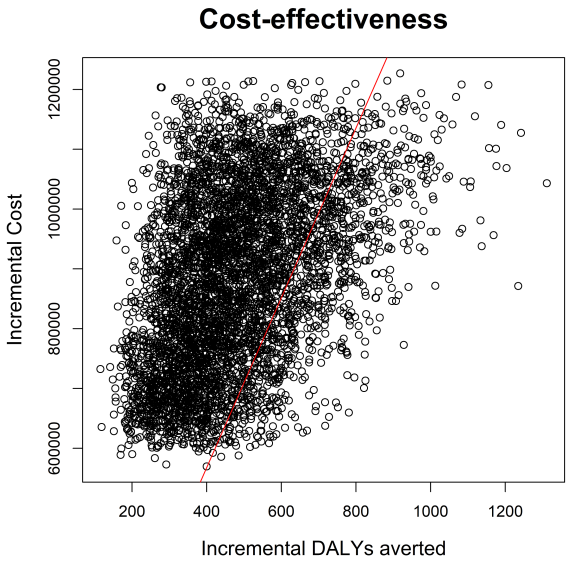


Figure 4a **Figure 4b**

Figure 4: Monte Carlo probabilistic sensitivity analysis

Monte Carlo probabilistic sensitivity analysis of 23 parameters, 5000 iterations for base case scenario, for vaccine prices at $3/dose (figure 5a) and $12/dose (figure 5b).The incremental cost of the proposed immunisation strategy is plotted against the y axis with the x axis displaying the incremental DALYs averted. Of the 5000 iterations, 99.92% fall below the cost effectiveness threshold of $1419.6 (red line) for the $3/dose case, while 18.12% fall below this threshold when the price is $12/dose. DALY – disability adjusted life year

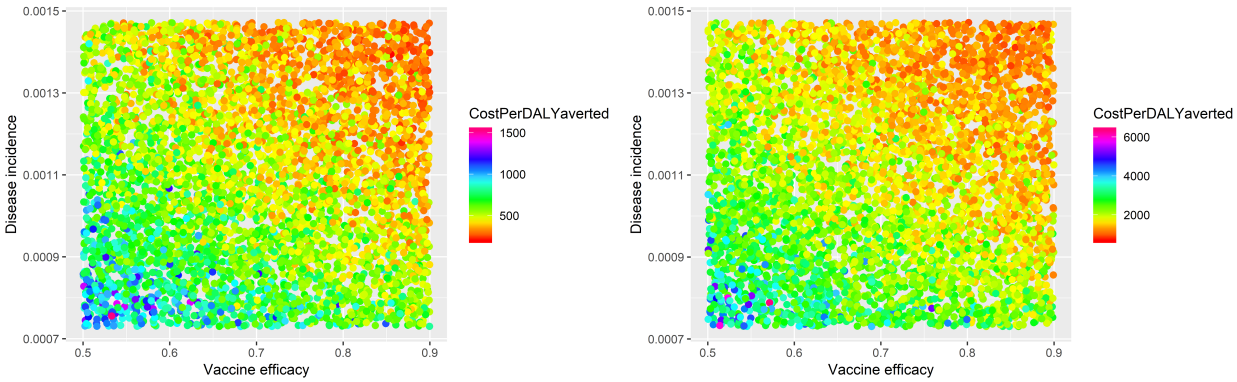


Figure 5a **Figure 5b**

Figure 5: Comparison of disease incidence and vaccine efficacy as drivers of vaccine cost-effectiveness in terms of Cost per DALY averted.

The chart represents Monte Carlo probabilistic sensitivity analysis of 5000 iterations, where other parameter values remain as in base case scenario. Vaccine price per dose for the base case scenario is $3 and $12 respectively (top to bottom). The incremental cost (£) per DALY averted of the maternal immunisation strategy compared to no preventative strategy is represented by nodes of varying colour depending on value (colour guides on figure's right side). DALY: Disability-adjusted life year. DALY – disability adjusted life years.

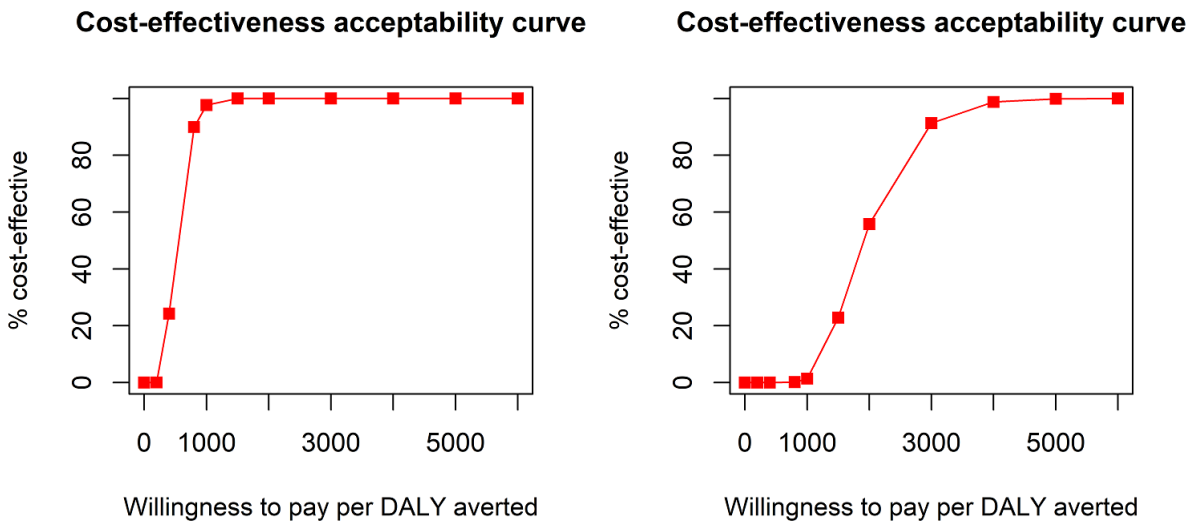


Figure 6a **Figure 6b**

Cost-effectiveness acceptability curve of the base case scenario (future costs and discount rate = 3%).

The graph displays the percentage of Monte Carlo iterations (total of 5000) for which the immunisation strategy is cost-effective, depending on the willingness of the healthcare system to pay

562 *(in $) for each DALY averted. Vaccine price per dose in the base case scenario is $3/dose (figure 6a)*

563 *and $12/dose (figure 6b).*

564

Table 1: demographic data, rates of each disease outcome and their associated disability weights, vaccine parameters and costs associated with treatment and vaccination.

Their ranges are included as a reference for the sensitivity analysis. Each source is included with relevant appendices, which include calculations of some parameters. 'Local data' refers to data from the Gambian cohort of mother-infant pairs studied. GBS – Group B Streptococcus

Parameter	Base-case value	Range	Distribution	Source
Birth in the Gambia (annual)				
Number of pregnancies	94,482	--	--	(12,32)
Number of livebirths	89,363	--	--	(32)
Number of stillbirths	4866	--	--	(12,45)
Number of preterm live births	9./ 804	--	--	(12,45)
Number of term livebirths	69196	--	--	(12,45)
Life expectancy	61	--	--	(46)
Reduced life expectancy of individuals with meningitis sequelae	30	--	Triangular (15,30,61)	(22)
Disease				
Neonatal GBS disease incidence per 1000 livebirths	1.3	0.73-1.472	Uniform	(12,17)
Rate of meningitis due to GBS	0.216	0.092-0.673	Uniform	(12,17)
Rate of sepsis due to GBS	0.431	0.216-0.647	Uniform	(12)
Rate of pneumonia due to GBS	0.353	0.177- 0.530	Uniform	(12)
Rate of sequelae from meningitis	0.18	0.13-0.22	Uniform	(19)
Rate of sequelae from sepsis survivors	0.369	0.127-0.381	Uniform	(17)
Death rate due to meningitis	0.213	0.046-0.390	Uniform	(18)
Death rate due to sepsis	0.500	0.250-0.750	Uniform	(16)
Death rate due to pneumonia	0.333	0.167-0.500	Uniform	(12)
Serotype coverage (%)	97	0.873, 0.97, 1	Triangular(	(12,30)
Vaccine				
Vaccine efficacy in term babies (%)	70	50-90	Uniform	(10,17)
Vaccine efficacy, preterm babies	83.1% of term (0.582)	0.416-0.748	--	(10,17) Appendix 3
Vaccine uptake rate	84.3%	0.5-0.9	Uniform	(12) Local data
In patient, provider treatment costs per case				
Meningitis	309	253-478	Gamma	(15) and (appendix)
Sepsis	106	53.1-159	Gamma	(15) and appendix
Pneumonia	111	88.8-155	Gamma	(15) and appendix
Family out of pocket costs				

Meningitis	56.2		-	(15) Appendix 4
Sepsis	45.3		-	(15) Appendix 4
Pneumonia	38.5		-	(15) Appendix 4
Meningitis sequelae	9.66	0-41.8	Uniform	(15) Appendix 4
Disability weights				
Meningitis sequelae [c] Sepsis sequelae [d]	0.260 0.221	0.153 - 0.364 0.141- 0.314	Uniform Uniform	(21) (16,47)
Vaccine costs				
Vaccination programme administration costs per vaccinated woman ($) Vaccine wastage rate (%)	0.456 10	0- 0.912 5-20	Gamma Uniform	(48) (48)

571

572

573 **Table 2: Health outcomes and costs before vaccine introduction and after introduction of a**

574 **vaccination programme at vaccine efficacies 50%, 70 and 90%.**

575 *The numbers of cases are categorised into those attributable to sepsis meningitis and pneumonia.*

576 *DALYs – Disability Adjusted Life Year; GBS – Group B Streptococcus; US$ - American dollars.*

	No vaccine	Vaccine efficacy (%)		
		50	70	90
DALYs	1384	837	616	395
Number of disease cases	116	70	52	33
Cases averted, (% averted)		**45.8**	**64.2 (55.5%)**	**82.7 (71.5%)**
Meningitis cases	25	15	11	7
Sepsis cases	45	30	22	14
Pneumonia cases	41	25	18	12
Number of GBS deaths	44	27	20	13
Number of deaths averted, (% averted)		**14 (32%)**	**24 (54.5%)**	**31 (70.5%)**
Meningitis deaths	5	3	2	2
Sepsis deaths	25	15	11	7
Pneumonia deaths	14	8	6	4
Number of babies with sequelae	13	8	6	4
Number of sequelae averted, %		**5** (40%)	**7 (50%)**	**9 (71.5%)**
Meningitis sequelae cases	4	2	2	1
Sepsis sequelae cases	9	6	4	3

Provider treatment costs (US$)	17,542	10,604	7804	4837
Out-of-pocket costs for treatment (US$)	5270	3186	2345	1453
Total treatment costs (US$)	22,812	13,790	10,149	6290

577